

Central Meson Production in ALICE

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The ALICE experiment at the Large Hadron Collider (LHC) at CERN consists of a central barrel, a muon spectrometer and of additional detectors for trigger and event classification purposes. The low transverse momentum threshold of the central barrel gives ALICE a unique opportunity to study the low mass sector of central production at the LHC. I will report on first analysis results of meson production in double gap events in proton-proton collisions at $\sqrt{s} = 7$ TeV and in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV.

1 Introduction

The ALICE experiment consists of a central barrel and of a forward muon spectrometer [1]. Additional detectors for trigger purposes and for event classification exist outside of the central barrel. Such a geometry allows the investigation of many topics of diffractive reactions at hadron colliders, for example the measurement of single and double diffractive dissociation cross sections and the study of central diffraction. The ALICE physics program foresees data taking in pp and PbPb collisions at nominal luminosities $\mathcal{L} = 5 \times 10^{30} \text{cm}^{-2} \text{s}^{-1}$ and $\mathcal{L} = 10^{27} \text{cm}^{-2} \text{s}^{-1}$, respectively. An asymmetric system pPb will be measured soon with a first test expected this year.

2 The ALICE Experiment

In the ALICE central barrel, momentum reconstruction and particle identification are achieved in the pseudorapidity range $-1.4 < \eta < 1.4$ combining the information from the Inner Tracking System (ITS) and the Time Projection Chamber (TPC). In the pseudorapidity range $-0.9 < \eta < 0.9$, the information from the Transition Radiation Detector (TRD) and the Time of Flight (TOF) system is in addition available. A muon spectrometer covers the range $-4.0 < \eta < -2.5$. At very forward angles, the energy flow is measured by Zero Degree Calorimeters (ZDC) [2]. Detectors for event classification and trigger purposes are located on both sides of the ALICE central barrel. First, the scintillator arrays V0A and V0C cover the pseudorapidity range $2.8 < \eta < 5.1$ and $-3.7 < \eta < -1.7$, respectively. The four- and eightfold segmentation in pseudorapidity and azimuth result in 32 individual

counters in each array. Second, a Forward Multiplicity Detector (FMD) based on silicon strip technology covers the pseudorapidity range $1.7 < \eta < 5.1$ and $-3.4 < \eta < -1.7$, respectively. Third, two arrays of Cherenkov radiators T0A and T0C deliver accurate timing for measuring the time of collisions. Figure 1 shows the pseudorapidity coverage of these detector systems.

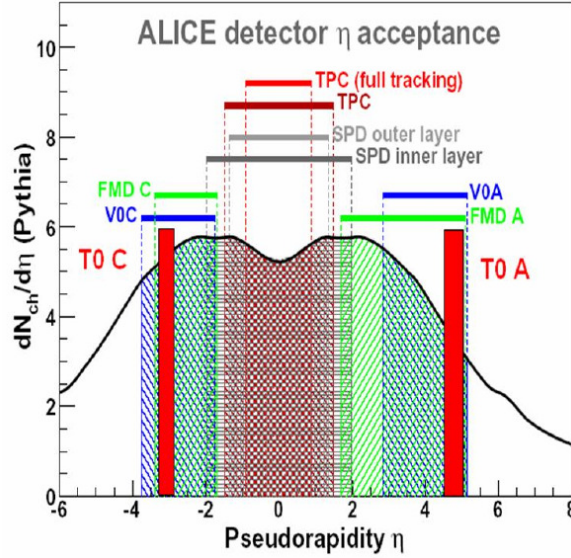


Figure 1: Pseudorapidity coverage of the ALICE detectors.

3 Central diffraction in ALICE

Central diffractive events are experimentally defined by activity in the central barrel and by no activity outside the central barrel. This condition can be implemented in the trigger at level zero (L0) by defining barrel activity as hits in the ITS pixel detector, or the TOF system. The gap condition is realized by the absence of V0 signals, hence a gap of two units on either barrel side can be defined at L0. In the offline analysis, the information from the V0, T0, FMD, SPD and TPC detectors define the gaps spanning the range $0.9 < \eta < 5.1$ and $-3.7 < \eta < -0.9$. Events with and without detector signals in these two ranges are defined to be no-gap and double gap events, respectively.

A rapidity gap can be due either to Pomeron, Reggeon or photon exchange. A double gap signature can therefore be induced by a combination of these exchanges. Pomeron-Pomeron events result in centrally produced states with quantum numbers $C = +1$ ($C = C$ -parity) and $I = 0$ ($I =$ isospin). The corresponding quantum numbers in photon-Pomeron induced events are $C = -1$ and $I = 0$ or $I = 1$ [3].

4 Central meson production in pp-collisions

In the years 2010-2011, ALICE recorded zero bias and minimum bias data in pp-collisions at a center-of-mass energy of $\sqrt{s} = 7$ TeV. The zero bias trigger was defined by beam bunches crossing at the ALICE interaction point, while the minimum bias trigger was derived by minimum activity in either the ITS pixel or the V0 detector. Events with double gap topology as described above are contained in this minimum bias trigger, hence central diffractive events were analyzed from the minimum bias data sample.

For the results presented below, a sample of 3.5×10^8 minimum bias events was analyzed. First, the fraction of events satisfying the gap condition described above was calculated. This fraction was found to be about 2×10^{-4} . Only runs where this fraction was calculated to be within 3σ of the average value of the corresponding distribution were further analyzed. This procedure resulted in about 7×10^4 double gap events. As a next step, the track multiplicity in the pseudorapidity range $-0.9 < \eta < 0.9$ was evaluated.

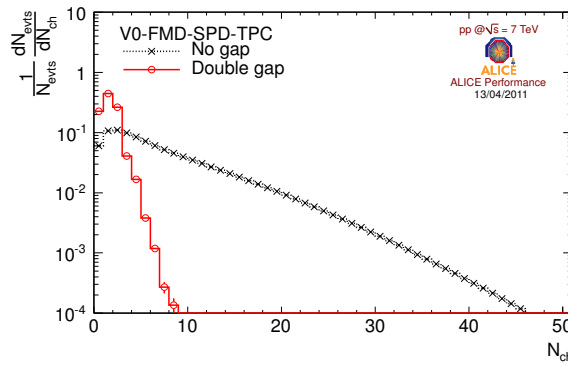


Figure 2: Track multiplicity within pseudorapidity range $-0.9 < \eta < 0.9$ for no-gap and double gap events.

Figure 2 shows the track multiplicity in the pseudorapidity range $-0.9 < \eta < 0.9$ for double and no-gap events. Very low transverse momentum tracks never reach the TPC which results in events with track multiplicity zero. The multiplicity distributions of the double and no-gap events clearly show different behaviors as demonstrated in Figure 2.

The specific energy loss dE/dx as measured by the TPC in combination with the TOF detector information identifies pions with transverse momenta $p_T \geq 300$ MeV/c. The events with exactly two pions are selected, and the invariant mass of the pion pairs is shown in Figure 3. These pion pairs can be of like or unlike sign charge. Like sign pion pairs can arise from two pion pair production with loss of one pion of same charge in each pair, either due to the low p_T cutoff described above, or due to the finite pseudorapidity coverage of the detectors used for defining the rapidity gap. For charge symmetric detector acceptances, the unlike sign pairs contain the signal plus background, whereas the like

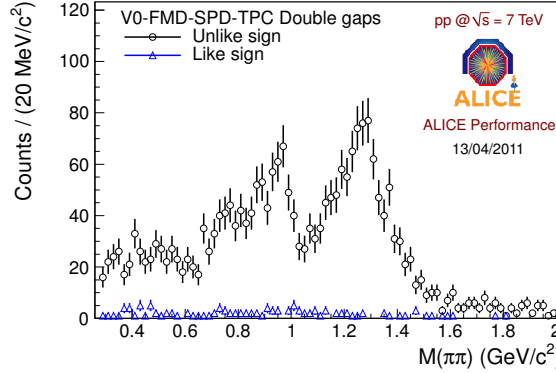


Figure 3: Invariant mass distribution of like and unlike sign pion pairs.

sign pairs represent the background. From the two distributions shown in Figure 3, the background is estimated to be less than 5%.

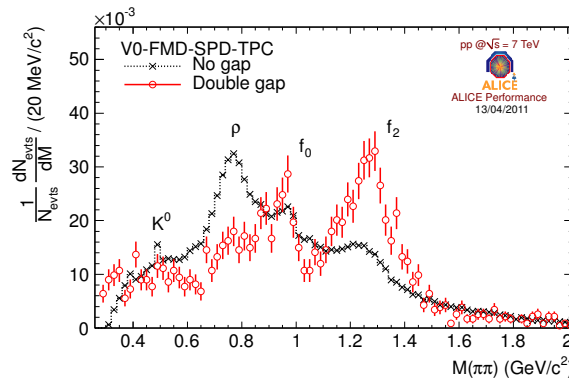


Figure 4: Pion pair invariant mass distribution for double and for no-gap events.

Figure 4 displays the normalized background corrected pion pair mass for double and no-gap events. The particle identification by the TOF detector requires the single track transverse momentum p_T to be larger than about 300 MeV/c. This single track p_T cut introduces a significant acceptance reduction for pair masses $M(\pi\pi) \leq 0.8 \text{ GeV}/c^2$ at low pair p_T . The distributions shown are not acceptance corrected. In the no-gap events, structures are seen from K_s^0 and ρ^0 -decays. Two additional structures are associated with $f_0(980)$ and $f_2(1270)$ decays. In the double gap distribution, the K_s^0 and ρ^0 are highly suppressed while the $f_0(980)$ and $f_2(1270)$ with quantum numbers $J^{PC} = (0, 2)^{++}$ are much enhanced. This enhancement of $J^{PC} = J^{++}$ states is evidence that the double gap condition used for analysing the minimum bias data sample selects events dominated by double Pomeron exchange.

5 Central meson production in PbPb-collisions

Diffraction and electromagnetic processes in PbPb-collisions show a variety of intriguing features [4, 5]. First, photoabsorption can lead to giant dipole resonance excitation with subsequent neutron decay. In such decays, the charge to mass ratio is modified. In addition, bound-free pair production also leads to a modified charge to mass ratio of one or both of the nuclei involved. Both processes contribute to the beam life time. Second, photon-photon processes result in electromagnetic production of pseudoscalars π^0, η, η' and of pairs of bosons $\pi^+\pi^-, K^+K^-$ and fermions $e^+e^-, \mu^+\mu^-, \tau^+\tau^-$. Third, photon-Pomeron processes can, for example, result in diffractive photoproduction of vector mesons $\rho^0, \phi, J/\Psi, Y$.

The first heavy ion run at the LHC took place in Nov-Dec 2010. In this period, about 12×10^6 minimum bias PbPb-collisions were recorded with the ALICE detectors. In addition to the minimum bias trigger, data were taken with two dedicated triggers for investigating meson production in the ALICE central barrel. First, a trigger OM2 based on number of TOF hits ≥ 2 was running. Second, a trigger CCUP2 defined by the logic combination: (TOF hits ≥ 2) AND (ITS pixel) AND (double gap condition) was defined.

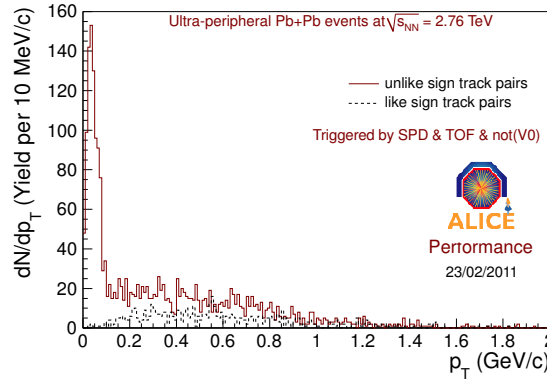


Figure 5: Transverse momentum of unlike and like sign CCUP2 triggered pairs in PbPb-collisions at $\sqrt{s_{NN}} = 2.76$ TeV.

The OM2 and CCUP2 triggered events with exactly two tracks in the central barrel were selected, and the pair transverse momentum was calculated. Both of these triggers result in similar pair p_T distributions. The pair p_T of CCUP2 triggered events is shown in Figure 5 for like and unlike sign pairs. The unlike sign distribution clearly shows a strong peak at $p_T \leq 100$ MeV/c consistent with coherent production off a Pb nucleus.

Figure 6 shows the invariant mass for the unlike sign CCUP2 triggered pairs with pair $p_T \leq 150$ MeV/c. This distribution is not corrected for finite detector acceptance and for detector resolution. The shape of the distribution shown in Figure 6 is consistent with production of the ρ^0 -meson with $J^{PC} = 1^{--}$. As for the p_T -distribution, the OM2 and CCUP2 triggers result in similar pair invariant mass distributions. Hence these results indicate that

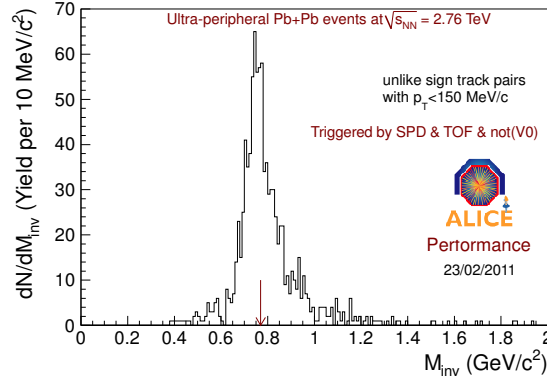


Figure 6: Invariant mass of unlike sign pairs with $p_T \leq 150$ MeV/c for CCUP2 triggered pairs in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV.

double gap events in PbPb collisions are not dominated by Pomeron-Pomeron events as is the case in proton-proton collisions.

6 Conclusions and Outlook

First analysis results show that central meson production in double gap events at LHC energies is consistent with the hypothesis of Pomeron-Pomeron and photon-Pomeron exchange in pp and PbPb-collisions, respectively. The next step in the study of these events will be a quantitative analysis of the results.

Acknowledgements

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References

- [1] K. Aamodt *et al.*, ALICE Collaboration, JINST **3** (2008) S08002
- [2] R. Arnaldi *et al.*, Nucl. Instr. and Meth. A **564** (2006) 235
- [3] O. Nachtmann, Annals of Physics, **209** (1991) 436, and references therein
- [4] G. Baur *et al.*, Phys. Rep. **364** (2002) 359
- [5] A.J. Baltz *et al.*, Phys. Rep. **458** (2008) 1